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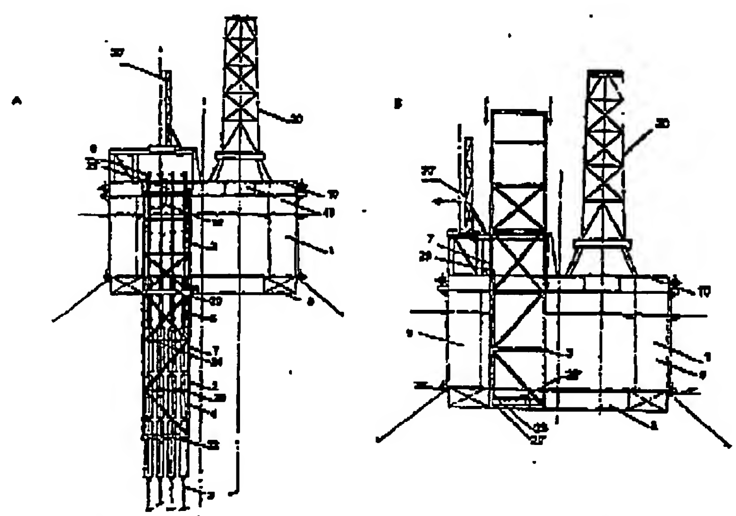
(54) Title: SYSTEM WITH A GUIDE FRAME FOR PETROLEUM PRODUCTION RISERS; A GUIDE FRAME FOR RISERS; RISER BUOYANCY ELEMENTS AND A SEMI-SUBMERSIBLE PRODUCTION PLATFORM

(57) Abstract



The invention describes a system with a system for use in petroleum production at sea, with a guide frame (2) for one or more riser pipes (3), on a semisubmersible production vessel (1), with one or more main buoyancy member (4) arranged separately on at least one riser (3) to carry the main part of the riser's (3) weight. Each riser (3) is arranged to separately carry a Christmas tree (6) on top, near the main deck (10) of the vessel (1). The guide frame (2) comprises vertical main elements (7) arranged to extend vertically downwards from the deck (10), through the splash zone and through the upper, more wave- and current- influenced zone of the sea. The guide frame (2) has horizontal guide plates (20) comprising vertically open cells formed of a horizontally arranged framework (21) of beams (21'), with lateral stabilization devices (24) for guiding the riser's (3) and the main buoyancy member's (4) vertical relative movement and restricting the horizontal relative movement with respect to the guide frame (2). The guide plates (20) are arranged in at least two levels on the guide frame (2); a lower guide plate (20) arranged in level with the lower ends of the vertical main elements' (7), and a guide plate (20) arranged in a level just below or near the splash zone. At least one main buoyancy member (4) is arranged for being held on the riser (3) in level with, and guided by the lateral stabilization devices (24) arranged in one or more guide plates (20), below the upper, more wave- and current-influenced zone near the sea surface, and with the risers (3) being essentially without buoyancy elements through the splash zone, for being less exposed to the water forces in the upper zone of the sea.

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SYSTEM WITH A GUIDE FRAME FOR PETROLEUM PRODUCTION RISERS; A GUIDE FRAME FOR RISERS; RISER BUOYANCY ELEMENTS AND A SEMI-SUBMERSIBLE PRODUCTION PLATFORM

Introduction.

This application concerns a frame for stabilizing risers on a petroleum production vessel, preferably for production risers with "dry" wellheads, i.e. with Christmas trees arranged on the deck of a freely floating platform. The petroleum production considered takes place at very large sea depths, very likely more than 1200 - 1600 meters.

Approach to the problem.

The invention is in one embodiment adapted for use in sea areas with the estimated wave height H_{max} being in the order of amplitudes between 5 and 10 m, thus considerably less than the H_{max} in the order of 25 - 30 m required for areas in the North Sea, conditions requiring considerably larger dimensioned and consequently heavier, more expensive vessels. A considerable problem in petroleum production at sea is to guide risers through the splash zone and the upper more current- and wave-affected zone below the sea surface. In this zone, large tensions, tension variations, bending moments, wave actions and accelerations occur on the risers and their connection points, for example Christmas trees.

Prior art.

The prior art is described in the patent specifications GB 2 147 549, US 5 558 467, and WO 95/28316. A similar shallow water construction which is not a vessel, and which cannot be applied in deep water, is described in GB 2 139 570.

"Spar" buoy.

A deep semisubmersible construction called a "Spar" buoy, may be adapted for production drilling, petroleum production or storing of petroleum fluids at sea. Such a design can consist of one single, heavily ballasted, column of very deep draught, having a relatively large buoyancy volume arranged at a high level in the column, at or below

the water surface, and having a column through the splash zone and a work deck above water. The lower ballasted part can comprise a framework. Such a column stabilized construction design has little heave or vertical movement but its large draught can entail that even small angular movements, as measured in degrees, still entails considerable horizontal accelerations near the top and the lower end of the construction. Such a deep column-stabilized design has an advantage in that it encloses the risers in the critical area from the splash zone at the sea surface and down to a depth more than 100 meters so that wave and current forces do not reach the upper part of the risers. Such a design has economic disadvantages in that the deep draught requires heavier plate dimensioning to resist the higher water pressure. Heavier dimensioned steel plates entails higher weight and price. The deep draught of the assembled operative platform requires assembly at deep draught in deep water near the field, meaning higher lifting and assembly costs.

WO 99/10230 "Buoyant substructure for offshore platform" describes a buoyant substructure floating vertically standing in the sea (e.g. as an offshore platform) comprising at least three separate columns being interconnected. At least one of the columns is arranged to be ballasted by the end which is arranged to have deep draught, where the columns are interconnected by short beams.

NO 174 920 "Flexible marine platform with surface production wells is described as a platform consisting of a rigid construction carrying a deck, pontoons fixed to the lower part of the rigid construction and a flexible construction constituted by columns fixed by their upper ends to the rigid construction and to the pontoons, and by their lower ends to a foundation arranged at the seabed, whereby the columns are in tension. Guide plates are illustrated, but no buoyancy elements on the risers.

Tensi n leg platforms.

Another solution for production platforms is tension

leg platforms, so-called TLP's. Tension leg platforms are anchored via vertical tension legs or tethers anchored to the sea bed. The risers of such a tension leg platform may be guided by guide plates described in the Norwegian patent applications NO 1998.3684 and NO 1998.3337, so that the risers get a parallel and small relative vertical movement relative to the platform deck and relative to each other. The tension legs are usually anchored with pile suction anchors, being vacuum-sucked down into the sediments in the sea bed, or gravity based structures on the seabed. At least two problems occur with such an anchoring solution:

a) At the large depths which may be in question: more than 1200 - 1600 meters, the seabed sediments may consist of less compacted unconsolidated organic mud, fine silt and clay particles with low density, low shear resistance and high water content, as distinct from glacially worked compacted clay/sand-containing sediments which constitute an essential part of the sea bed in the North Sea and the Norwegian Sea.

b) The sea bed can contain petroleum fractions forming so-called "hydrates" being kept in a partial frozen phase at shallow depths below the sea bed and is presumed to be deposited from escaping petroleum fluids from deeper geological layers at higher temperatures. These hydrates are unstable and can pass to the gas/liquid phase if they are supplied with heat. In a sedimentary basin, deeper geological layers usually have a higher temperature than the surface layers. Petroleum production entails a heat transfer from the upwardly flowing/rising petroleum fluids in top of the well, to and may result in an unwanted fluidization of hydrates in layers close to the seabed. Thus, there is a risk of gas formation at the suction anchors and a risk for sudden loss of tension in a tension leg.

In deeper waters the separation between the risers must be large in order to avoid collision during hydrodynamic drag. This separation usually requires a larger and thus heavi r tension leg platform.

Semisubmersible platform.

A third solution is ordinary column stabilized or semisubmersible constructions in the form of platforms. An essential problem with semisubmersible constructions with an open moonpool is that the production risers will hang freely movable and unstabilized through the splash zone and the upper water masses. This is difficult if there are buoyancy members on the risers, and especially if the buoyancy members are arranged in the splash zone, because, as mentioned above, problems with wave forces laterally and vertically on the buoyancy members and the risers occur.

Short summary of the invention

A solution to the above mentioned problems is given according to one embodiment of the invention as defined in the patent claims enclosed: A system for use in petroleum production at sea, with a guide frame for one or more riser pipes on a semisubmersible production vessel with one or more main buoyancy member arranged separately on at least one riser to carry the main part of the riser's weight. Each riser is arranged for separately carrying a Christmas tree on top, near the deck of the vessel. The guide frame comprises vertical main elements arranged to extend vertically downwards from the deck, through the splash zone and through the upper, more wave- and current-influenced zone of the sea, down to a depth of about 50 - 150 meters below the sea surface, where drag forces are less pronounced. The novel features by the invention is as follows:

* The guide frame has horizontal guide plates comprising vertically open cells formed of a horizontally arranged framework, preferably of beams, with lateral stabilization devices for guiding the risers' and the main buoyancy members' vertical relative movement and restricting the horizontal relative movement with respect to the guide frame.

* The guide plates are arranged in at least two levels on the guide frame: a lower guide plate arranged in level with the lower ends of the vertical main elements, and another guide plate arranged in a level just below or near the

splash zone.

* One main buoyancy member is arranged for being held on the riser preferably in level with, and guided by the lateral stabilization devices arranged in the lower guide plate, below the upper, more wave- and current-influenced zone near the sea surface, and with the risers being essentially without buoyancy elements through the splash zone, for being less exposed to the environmental water forces, e.g. drag, in the upper zone of the sea.

More specifically, the invention concerns a framework for arrangement in a production moonpool in a semisubmersible platform. In a preferred embodiment the semisubmersible platform has a square-shaped ring pontoon. The main proportion of wave-influence and current, exerting horizontal drag forces on risers, takes place in the upper 150 meters below the sea surface. These horizontal forces normally decrease strongly with increasing depth below the surface. According to a preferred embodiment of the invention, each riser is arranged with main buoyancy members or, so-called "cans", arranged below the splash zone and the most strongly wave-influenced zone, so that they carry the main part of the weight of the riser in the sea. Thus the essential part of the carrying capacity represented by the wide-diameter buoyancy members is arranged in a depth zone where weaker drag forces are exerted. The diameter of auxiliary buoyancy elements is smaller further up, in order not to be so strongly affected by the more strongly wave- and current influencing zone of the water. Preferably the riser pipe is "naked" through the splash zone, giving minimum attack surface for waves and current. The auxiliary buoyancy members may be arranged further upwards on the riser, to carry the local weight of the risers above the main buoyancy members. Below the buoyancy members, the risers are in tension. At a certain level between the buoyancy members and the wellhead on top of the riser, the longitudinal forces in the riser pipe pass from tension to compression. Thus each riser pipe according to the invention will carry a wellhead on top, being vertically arranged for

free vertical movement relative to the platform deck. By reducing the exposed diameter of equipment crossing the splash zone, drag forces incurred by water currents and waves that pull or bend the riser laterally are minimized. The framework according to the invention is arranged to stiffen up the risers laterally in the current- and wave-influenced zone. In a preferred embodiment of the invention the framework extends to a depth of about 70 to 80 meters. The framework comprises, in a preferred embodiment of the invention, several levels with grid-like horizontal frames with one opening for each riser, with the opening preferably also containing a main or auxiliary buoyancy member. In the preferred embodiment, all openings for risers are sufficiently wide in order for the main buoyancy members to be set down through the framework right from the top. The largest buoyancy members are arranged in the deeper, less wave-influenced parts of the framework. This invention differs in this manner essentially from a so-called "Spar"-buoy having the main buoyancy members arranged in or near the splash zone, protected through the splash zone by the surrounding cylindrical wall constituted by the column of the buoy.

Short description of the drawings.

The invention is illustrated in the following drawing figures stating non-limiting examples of an embodiment of the invention.

Fig. 1a illustrates a combined elevation view and vertical section of a semisubmersible platform, having a ring pontoon, and a partial view, partial vertical section of the guide frame for risers with buoyancy elements according to the invention. In a preferred embodiment, a separate wellhead derrick is arranged mobile on two sets of rails so that the wellhead derrick can be moved over a selected well in the production moonpool. As illustrated, a drilling derrick may be fixed.

Fig. 1b shows similarly to Fig. 1a, a situation with the

guide frame for risers being raised with its lower end generally to the same level as the lower edge (bottom) of the ring pontoon. A work-over derrick is here illustrated being driven aside from the production moonpool to give free way over the production moonpool for elevating the frame according to the invention.

Fig. 2 shows a plan view and partial section of a guide plate in one level of the guide frame, with stabilizing devices for stabilizing a riser pipe and a buoyancy element in the horizontal directions.

Fig. 3 illustrates a detail of a lower hinge point for attachment of a vertical member of the guide frame against a lower edge of the ring pontoon (section view).

Fig. 4 is a section view illustrating a flange on the upper end of the vertical main members of the frame, the flange being arranged to be hung up in a frame in the production deck of the platform.

Fig. 4b is a more detailed vertical section of the top deck of the guide frame and illustrating a Christmas tree arranged standing on the riser pipe's upper end.

Fig. 4c shows a plan view of the top deck of the guide frame with openings in each cell for a flexible U-hose leading from a projecting wing valve and further connected directly or indirectly to pipes on the production deck.

Figure 5a shows, in an isometric illustration seen from a position above the horizontal, a semisubmersible platform with a guide frame according to the invention, the guide frame being raised or jacked up.

Figure 5b shows is an isometric illustration as seen from a position below the horizontal, a semisubmersible platform with a guide frame according to the invention, the guide frame being lowered to a submerged operational position.

Some risers, each provided with buoyancy elements are illustrated.

Figure 5c illustrates a preferred embodiment of the invention, with a mobile work-over derrick arranged over the guide frame with 4x4 dry wellheads and risers tensioned by buoyancy elements arranged as keeljoints.

Figure 6 shows a rough deck plan view of a platform in a system with flexible pipes connecting the risers to the production deck according to a preferred embodiment of the invention.

Fig. 7 is a section of the main deck and shows the derrick arranged movable on two crossing sets of rails one set being normal to the sectional plan.

Fig. 8 is a graph of an example of potential drag forces which can be exerted on a riser by current and waves.

Fig. 9 shows graphs of tension and strain in the riser according to a preferred embodiment of the invention.

Fig. 10 is the buoyancy and weight along the riser according to a preferred embodiment of the invention.

Fig. 11 illustrates a vertical and a horizontal section of a buoyancy element according to the invention.

Description of a preferred embodiment of the invention.

Fig. 1a shows a vertical section of a system according to the invention, comprising a semisubmersible platform or vessel 1 with one or more pontoons 8, in a preferred embodiment a ring pontoon 8, with a partial view, partial vertical section of a guide frame 2 for one or more riser pipes 3. The guide frame 2 is illustrated arranged in a lower or "submerged" operational position, with the upper part of the guide frame 2 being arranged near the level of the main or weather deck 10 of the platform, with the frame

2 extending through the splash zone and down through the most strongly influenced wave- and current-influenced zone, to below the pontoon 8.

The guide frame 2 is arranged for one or more risers 3 and one or more main buoyancy members 4 and, in a preferred embodiment, auxiliary buoyancy members 5 arranged to carry the weight of the riser 3. The buoyancy members 4,5 are arranged separately on each riser. In a preferred embodiment of the invention, Christmas trees 6 are carried on top of each riser.

Figure 1 shows an embodiment of the invention, comprising:

a) A guide frame 2 in the form of a framework with vertical main members 7 arranged for extending from the deck 10 of the vessel 1, through the splash zone and down through the most strongly influenced wave- and current-influenced zone to a depth of about 50 - 150 meters below the sea surface. The vertical members 7 may have rectangular cross-section.

b) Guide plates 20 for the risers arranged in at least two elevation levels: in level with the lower ends of the vertical main members 7, in level at or just beneath the splash zone, and preferably at deck level and one or more upper- and intermediate levels.

c) The guide plates 20 have openings 22 constituted by a framework 21 (see Fig. 2) arranged for setting of riser pipes 3 and buoyancy members 4,5 from the top. Each guide plate 20 has stabilizing means 24 (see Fig. 2) for lateral stabilization of the riser pipes 3 and the main- or auxiliary buoyancy members 4,5.

d) The largest buoyancy members or main buoyancy members 4 carrying the main weight of the risers 3, are arranged on the each riser pipe in an elevation level near the lower part of the vertical main members 7 of the guide frame 2. The risers are arranged preferably entirely without buoyancy elements through the splash zone. The reason for having no buoyancy element in the splash zone is illustrated in figure 8. Fig. 8 shows that the largest drag force, that is, the zone with current and wave exerting forces on the riser 3,

appear in the splash zone and in the upper water masses where waves and current are most dominant. The water movements of surface waves change directions and decrease with increasing depth below the sea surface. The drag force from waves and water current on any exposed rigid element, here a stiff riser with buoyancy elements 4,5, increases with increasing diameter, here the diameter of the riser or the buoyancy member. Because the largest forces appear in the upper masses of water, the radius or diameter of the risers is thus sought to be as small as possible through the splash zone, and with the main buoyancy members 4 with relatively large radius kept rather deeper where the movements of the water are calmer and exert less drag. In addition, the risers 3 and the buoyancy elements 4,5 are restricted against horizontal movements in all levels in the guide frame 2, but are be free to move vertically relative to the guide frame 2. Thus, the vertical movements of each riser 3 become independent of the other risers 3, and also independent of the vertical movements of the platform.

The lower buoyancy can 4 will in a preferred embodiment of the invention form a "keeljoint" forming the riser's 3 entrance into the guide frame 2 which is the lower part of the production platform 1. It is, of course, possible to arrange an extension of our preferred embodiment by extending the vertical main elements below the lower frame 20 holding the lower buoyancy element 4, to arrange a separate keeljoint for the riser 3.

Fig. 1b illustrates the same vertical section and view as Fig. 1a. In a preferred embodiment of the invention the guide frame 2 for risers 3 is arranged to be raised with the lower end of the vertical main elements 7 mainly to the same level as the lower end of the ring pontoon 8. This position for the guide frame 2 allows for transit with considerably reduced draught and decreased water resistance when platform 1 is deballasted up to be floating on the ring pontoon or the pontoons 8, so that the vessel 1 becomes stable.

Hoisting means 26 (not shown) are arranged to move the guide frame 2 vertically between an upper position with the

lower end of the guide frame 2 arranged in level with the main pontoon 8 or otherwise bottom of the vessel, and a lower position with the upper end of the guide frame 2 in level with the deck 10. The hoisting means 26 can comprise wire drum winches 27 (not shown) on the guide frame and the vessel. Other hoisting devices can be of a hydraulic, mechanical or electromechanical type, and belongs to the known art. The hoisting means 26 may also be helped by tanks 28 on the part of the guide frame 2 or guide plates 20 being arranged for being lowered below the draft waterline of the vessel 1. The tanks 28 can be arranged both for buoyancy or ballasting of the guide frame 2. The tanks can be provided with compressed-air means 29 and valves 29' or pumps arranged for draining of the water content of the tanks being under the sea surface. The valves 29' can close the tanks.

Fig. 2 and Fig. 3 illustrates a plan view and partial section of a guide plate 20 arranged in a level in the guide frame 2. In the current section, the guide frame 2 is held towards a reinforced inner facing side of the pontoon 8. A fixed holding rail 12' is held vertically in a distance from the inner facing side of the pontoon 8 and arranged with a flat holding surface facing the pontoon, and arranged for holding a sidewards extending protruding rail 14 arranged on a vertical main member 7 designed for lying closer to the pontoon 8. A holding means 12 is arranged for exerting a horizontal force on the opposite side of the protruding rail 14, forcing the protruding rail 14 towards the fixed holding rail 12'.

Fig. 2 further illustrates the guide plate 20 comprising, as an example, 4 x 4 square cells formed of a horizontally arranged framework 21 of beams 21' in each guide plate 20. The holding means 12 can comprise a guiding means with the fixed holding rail 12' guiding and stabilizing the guide frame 2, also when it is not located in the operative, lower, position, but also when the guide frame is kept in a completely or partially raised position.

The stabilizing devices 24 for sideways stabilizing of the riser pipes 3 and the main- or auxiliary buoyancy elements 4,5 may in a preferred embodiment comprise wheels 17 with horizontal axle 17' arranged in the openings formed by the preferably square cells formed by the horizontally lying framework 21 of beams 21' in the guide plates 20. The wheels' tread surface is directed towards the riser axis and arranged to roll against the main buoyancy elements 4 or auxiliary buoyancy elements 5, or against the riser pipe 3 in its axial direction, in order for the buoyancy elements 4,5 and the riser pipe 3 to be free to move vertically with respect to the guide plates 20 and the semisubmersible platform 1. In a preferred embodiment, the wheels 17 are arranged in groups, each group comprising four wheels 17 arranged in each square-shaped cell opening in the framework 21. Each wheel 17 is arranged essentially diagonally near a corner in the square cell, with the axle 17' extending horizontally and having an angle of about 40 to 45 degrees deviation from a beam 21' as illustrated in fig. 2. This arrangement makes space for maintenance of the wheels 17 possible from the free end of the axle 17'. In a preferred embodiment each wheel 17 is arranged somewhat displaced away from a diagonal line of the cell, allowing sufficient space for a maintenance tool (not illustrated) arranged to exchange and replace a worn or damaged wheel 17 with a replacement wheel 17. A maintenance tool (not illustrated) may be arranged for running vertically inside adjacent square cells in the frameworks 21. In the upper parts of the guide frame 2 where the riser does not need buoyancy elements, wheels may be arranged on splittable plates (121, not illustrated) being hinged in the beams 21' and arranged for being turned 90 degrees up and away from the riser pipe 3, in order to give free path for buoyancy elements 4,5 while these are to be set or taken up, and while a maintenance tool shall pass from the top deck 23 (near the work deck 10) of the guide frame 2, down between the beams 21' of one or more the guide plates 20.

Fig. 3 illustrates an embodiment of the lower holding

means 12 being arranged for attachment of the vertical member 7 of the guide frame 2 with a nodal point of a horizontal guide plate 20 being held against the reinforced inner face and the lower edge of the ring pontoon 8. In this way horizontal forces from the guide frame 2 are guided straightly along a line into the bottom plates of the pontoon 8, and thus reducing the torque influence of the guide frame 2 on the pontoon 8.

Fig. 4 is a section of the guide frame 2 in an embodiment having an outer flange 25 being arranged on the outside near the upper end of the vertical main members 7, and near the top deck 23 by of the guide frame 2. The flange 25 is arranged for being hung up in a production moonpool frame 25' in the platform deck or production deck 10. In a preferred embodiment, the production moonpool frame 25' is arranged inside and near of a vertical projection of the pontoon.

Fig. 4b is a more detailed section of top deck 23 of the guide frame 2 with a dry wellhead and Christmas tree 6 arranged standing on the upper end of the riser 2. The riser 3 is locked laterally in the top deck 23 but is allowed to be free to move vertically (The riser pipe 3 is anchored to the seabed and held in tension by the buoyancy members 4,5. The semisubmersible platform is free to move vertically with respect to the riser pipe 3). Petroleum fluids are conducted via a flexible hose 18 from a wing valve 6' on the Christmas tree 6, hanging in a U-shape and back up through the platform deck 10 for connection to a valve on the deck 10, where processing and/or export can take place. Alternatively, the U-shaped hose 18 is led up through the top deck 23 of the guide frame as illustrated in Fig. 4B, or entirely above the top deck 23. In a preferred embodiment, a maximum free stroke length of 10000 mm is estimated for the riser through the top deck 23. The stroke length must be adapted to a locally expected maximum wave amplitude.

Fig. 4c shows a plan view of the top deck 23 of the

guide frame with openings in each cell for the flexible U-hose 18 leading from the projecting wing valve 6' as described under Fig. 4b. In figure 4c, 1/4 of the wing valves 6' are located with oblique azimuth in relation to the rows of riser pipes 3, so that the hose 18 is free to pass freely with respect to the beams 21' of the top deck 23 and the riser pipes 3.

Figure 5a shows (see also Fig. 1b) a perspective view of the vessel with the guide frame when it is raised or jacked up with the lower end of the guide frame 2 in level with lower edge of the pontoon 8 (see also Fig. 1a).

Fig. 5b shows an isometric illustration of the vessel with the guide frame 2 in submerged operational position and with risers 3, main buoyancy members 4 and auxiliary buoyancy members 5 attached to the risers 3 and kept in the guide plates 20 in the guide frame 2.

Figure 5c illustrates a preferred embodiment of the invention, with a mobile work-over derrick 31' arranged over the guide frame 2 with 4x4 dry wellheads 6 and risers 3 tensioned by buoyancy elements 4 arranged as keeljoints, and optionally auxiliary buoyancy elements 5 arranged above the buoyancy elements 4, and below the splash zone. In this preferred embodiment there is a work-over/wellhead derrick 31' only, without a drilling derrick. Two guide frames may be arranged, one on either side of the work deck and inside and adjacent to the ring pontoon 8.

Fig. 6 is a rough deck plan view of a system according a preferred embodiment of the invention, with a platform 1 with square ring pontoon 8 with a moonpool for production riser pipes 3 and a moonpool 40 for drilling. The drilling moonpool 40 will not be further described here. A derrick 30 is illustrated. A wellhead derrick 30' (illustrated in Fig. 1A, Fig. 1b and Fig. 7) for the riser moonpool 25 is arranged to be movable on a pair of parallel horizontal first rails 32, and a pair of additional horizontal parallel

second rails 31 (see Fig. 7) arranged at 90 degrees angle with the first rails 32. The wellhead derrick 30' is arranged for working above any freely selected Christmas tree 6 or riser 3 in the riser moonpool 25'. The top deck 23 of guide frame 2 is illustrated having 4 x 4 cells, as an example, where 16 Christmas trees 6 are illustrated, each having an obliquely arranged wing valve 6' connected to valves on the deck, and further connected to a manifold 51 and a pipe 51 to a separator 50. From the separator 50 there are arranged two pipelines 54, 55: one leading petroleum fluids to export pumps 57 which further leads to a petroleum fluid export device 60, for example an export riser 60, an another pipeline 55 leading to a "knock out drum" 55' and further to a flare 56.

Fig. 6 and Fig. 1B also illustrates that one pair of the rails, here the rails 32, are arranged with a part extending outside the riser moonpool 25' in order for the wellhead derrick 30' (in a preferred embodiment together with the rails 31) can be displaced horizontally outside and away from the space above the riser moonpool 25' and the guide frame 2, so that the guide frame 2 may be elevated to its upper position as illustrated in Fig. 1B.

Fig. 6 shows a piping arrangement with a boiler 70, a heat exchanger 71 and brine pumps 72 for injection of heated sea water through the annulus 32 of the risers 3 between the tubing pipe wall and casing pipe wall. Potential problems are present at the cooling of the petroleum fluid during transport in pipelines. Precipitation of waxes or hydrates can occur when the temperature of the petroleum fluid falls below a temperature depending on the composition of the petroleum fluid, and also depending on the pressure. Hydrate precipitation can take place when the temperature falls below typically 20 degrees C, depending on wellfluid composition. The colder sea water will at normal conditions cool the petroleum fluid down during transport of the fluid up through the extremely long riser, so that waxes and hydrates are precipitated towards the riser pip ,

particularly in a startup or a shutdown situation. The same conditions constitutes a considerable problem in connection with transport from widespread satellite wells on the sea bed, with a large distance from a central production platform. In the preferred embodiment, this is solved by means of the injection arrangement comprising brine pumps 72 for heated sea water to the annulus of the risers, so that the temperature of the petroleum fluid does not fall below the critical temperature for the precipitation of waxes or other undesired precipitations.

Figure 7 is a section of the platform and illustrates the fixed drilling derrick 30 and the completion or work-over derrick 30' arranged movable on rails 31 normally to the sectional plan. The derrick 30' can thus be arranged above wells 6 for maintenance or while a new well shall be completed. A new well can be drilled by the derrick 30 at the same time as the derrick 30' conducts completion of a previously drilled well,, or used for setting of production risers 3, setting of main buoyancy elements 4 on the riser 3 below the upper wave-influenced zone; auxiliary buoyancy members 5 on the riser above the main buoyancy members 4 and below the splash zone; glide bearing cups or wheels 17 for vertical free stroke of risers and buoyancy elements through the guide plates 20, mounting of a Christmas tree 6 on each riser and connection via jumpers preferably comprising flexible hoses 18.

Figure 8 is a graph of an example of those drag forces which may be exerted on a riser because of forces from current and waves, here shown with the zero level at the sea surface/draught line for a half submerged position of the vessel 1.

Figure 9 is a graph of tension in the riser according to a preferred embodiment of the invention, together with the estimated maximum horizontal strain on a riser according to a statistical forecast of the maximum 100-year sea state based on meteorological specifications for a sea area

outside the coastal area West Africa, for example Angola.

Figure 10 illustrates the buoyancy of a riser (including buoyancy elements) and weight being estimated stepwise along the riser according to a preferred embodiment of the invention. In each level is

Net buoyancy = local buoyancy - local weight.

In the example shown in figure 10, the lower main buoyancy members 4 are arranged and attached to the riser in the level approximately 80 meters below the sea surface. It is evident that the auxiliary buoyancy members 5 arranged above the main buoyancy elements 4 almost only contributes to carry the local weight of the riser 3. Here it is shown that the buoyancy becomes negative in the level just above the top of the auxiliary buoyancy members 5. This results in that the Christmas tree 6 stands or "rides" on the top end of the vertical stiff riser pipe 3 as intended, resting on the buoyancy members 4,5 and following the vertical movement of these in the sea. The Christmas tree 6 is according to a preferred embodiment of the invention thus in free movement vertically in relation to the production deck 10 or the top deck 23 of the guide frame, and connected as described above.

Figure 11 illustrates a preferred embodiment of the invention showing details of a buoyancy elements 4,5 and its design for cooperating with the wheels 17. Each buoyancy element has an outer right circular cylindrical wall 44 constituting the outer vertical sidewall, and circular endpieces 46 having their periphery welded to the upper and lower ends of the cylindrical wall 44. An inner pipe 47 extends centrally, axially inside the cylindrical wall 44 and constitutes an open channel 47' through central holes in both endpieces 46. The open channel 47' has a larger inner diameter than the outer diameter of a riser pipe 3 section which shall be arranged inside the buoyancy element 4,5. The larger inner diameter of the open channel 47' allows the

riser pipe to curve in order to allow distribution of bend of the section of the riser pipe 3, which is attached to the radially inner wall of the inner pipe 47 in two levels only: in an upper level by a hangoff shoulder 43A arranged at the riser pipe 3 section and being clamped by an upper clamp arrangement 43B taking up both horizontal and vertical forces, and in a lower level by a horizontally supporting pair 42A on the riser pipe 3 section and 42B arranged on the radially inner wall of the inner pipe 47, allowing a short free relative vertical movement. Thus the section of a riser pipe 3 is allowed to both to stretch and contract, and also to bend somewhat inside the inner pipe 47, and is only fixed vertically to the inner pipe in one upper level at 43A,B, and free to move vertically at 42A,B. Below the lower buoyancy member 4 the riser pipe can be tapered off downwards.

The wheels 17 arranged for running in a relative movement against a buoyancy element 4,5 shall in the preferred embodiment run on the outside of the cylindrical wall 44, which is backed by a number of reinforcing vertical bulkheads 45 arranged between the inside of the outer cylindrical wall 44 and the corresponding radially "outer" surface of the inner pipe 47, The number of bulkheads 45 corresponds to the number of wheels 17 arranged around the section in each cell. In a preferred embodiment the number of bulkheads and wheels is four. The bulkheads 45 divide the buoyancy members into water-tight compartments preventing complete loss of buoyancy force if a water leakage occurs. The wheels 17 may optionally be arranged in pairs in vertically running bogeys 170 (not shown) rotatable around bogey axles 170' being parallel with the axles 17', and preferably also arranged in each corner of a cell defined by the beams 21' in a guide plate 20.

For individual ballasting and deballasting of the buoyancy members 4,5, each buoyancy member may be provided with compressed air means and corresponding valves and pipes as illustrated in Fig. 11, arranged for filling or draining of the water containment of the buoyancy members 4,5.

In alternative embodiments of the invention, the guide frame 2 may be entirely or partially submersible for connection to the semisubmersible vessel 1 from the side or underside of the vessel 1. The guide frame 2 can be built separately from the vessel 1 and later be installed, elevated in transit, and thereafter lowered before operation on site. The possibility for raising and lowering the guide frame shall not to be construed as a limitation to the invention.

Claims

1. A system for use in petroleum production at sea, with a guide frame (2) for one or more risers (3), on a semi-submersible production vessel (1), with one or more main buoyancy member (4) arranged separately on at least one riser (3) to carry the main part of the riser's (3) weight,

each riser (3) arranged to separately carry a Christmas tree (6) on top, near the deck (10) of the vessel (1),

the guide frame (2) comprising vertical main elements (7) arranged to extend vertically downwards from the deck (10), through the splash zone and through the upper, more wave- and current-influenced zone of the sea,
characterized by

the guide frame (2) having horizontal guide plates (20) comprising vertically open cells formed of a horizontally arranged framework (21) of beams (21'), with lateral stabilization devices (24) for guiding the risers' (3) and the main buoyancy members' (4) vertical relative movement and restricting the horizontal relative movement with respect to the guide frame (2),

the guide plates (20) being arranged in at least two levels on the guide frame (2); a lower guide plate (20) arranged in level with the lower ends of the vertical main elements (7), and a guide plate (20) arranged in a level just below or near the splash zone, and

that at least one main buoyancy member (4) is arranged for being held on the riser (3) in level with, and guided by the lateral stabilization devices (24) arranged in one or more guide plates (20), below the upper, more wave- and current-influenced zone near the sea surface, and with the risers (3) being essentially without buoyancy elements through the splash zone, for being less exposed to the water forces in the upper zone of the sea.

2. A system according to claim 1,
characterized in
that at least one main buoyancy member (4) is arranged for being held on the riser (3) in level with, and guided by the

lateral stabilization devices (24) arranged in the lower guide plate (20), forming a keeljoint between the riser (3) and the vessel (1).

3. A system according to claim 1 or 2, characterized by
the main buoyancy element (4) essentially comprising a right circular cylinder with an outer cylindrical [vertical] sidewall (44) closed by circular endpieces (46) at the upper and lower ends, comprising an inner pipe (47) extending centrally and axially inside the cylindrical wall (44) and forming an open channel (47') through centrally arranged holes in both endpieces (46), the open channel (47') having an inner diameter being larger than the outer diameter of a section of riser pipe (3), to provide room for curving of the section of riser pipe (3) inside the channel (47').

4. A system according to claim 1 or 2, characterized by
at least one auxiliary buoyancy member (5) similar to, but having lesser diameter than the main buoyancy members (4), and arranged for being attached on a riser pipe (3) above the at least one main buoyancy member (4) and essentially below the splash zone, and being arranged to carry the riser pipe's (3) local weight above the main buoyancy member (4).

5. A system according to claim 3, or 4, characterized by
an upper hangoff shoulder (43A) arranged at a section of a riser pipe (3) and arranged for being clamped by an upper clamp arrangement (43B) in the central channel (47'), designed for taking up both horizontal and vertical forces between the buoyancy element (4,5) and the riser pipe (3) section, and a pair of horizontally supporting member (42A) on the riser pipe (3) section cooperating with a member (42B) in the central channel (47'), allowing a relatively short free relative vertical movement of the riser pipe (3) in the channel (47').

6. A system according to one of claims 1-5, characterized in that the stabilizing devices (24) for sideways stabilizing of the riser pipes (3) and the main- or auxiliary buoyancy elements (4,5) comprise wheels (17) with their axles (17') arranged in the openings formed by the cells formed by the horizontally lying framework (21) of beams (21') in the guide plates (20), arranged with the wheels's (17) tread surface to roll against the main buoyancy elements (4) or auxiliary buoyancy elements (5), or against the riser pipe (3) in the axial (operationally vertical) direction, in order for the buoyancy elements (4,5) and the riser pipe (3) to be guided vertically with respect to the guide frame (2) and the semisubmersible platform (1).

7. A system according to claim 6, characterized in that each wheel (17) is arranged essentially diagonally near a framework node in a cell formed of beams (21') in a guide plate (20), directed towards the riser centerline, with the axle (17') extending horizontally and having an angle of about 40 to 45 degrees deviation from a beam (21').

8. A system according to claim 6 or 7, characterized in that the buoyancy members (4,5) are provided by radial, standing bulkheads (45) arranged between the inside of the outer cylindrical wall (44) and the corresponding radially "outer" cylindrical surface of the inner pipe (47), the number of bulkheads (45) corresponding to the number of wheels (17) arranged around the buoyancy member (4,5), the bulkheads (45) being arranged as a backing of the cylindrical wall (44) against forces from the wheels (17) running on the outside of the cylindrical wall (44).

9. A system according to claim 4 or 7, characterized in that the at least one pair of the wheels (17) is arranged in a pair in a vertically running bogie (170) rotatable around

a bogie axle (170') being parallel with the axle (17').

10. A system according to one of claim 1-9,
characterized in
that all levels of the guide plates (20) comprising vertically open cells formed of the horizontally arranged framework (21) of beams (21') are arranged for setting of at least the largest/main buoyancy members (4) on the riser pipe (3) from above.

11. A system according to claim 1,
characterized in
at least one intermediately arranged guide plates (20) arranged in a separate level on the guide frame (2); above the lower guide plate (20) arranged in level with the lower ends of the vertical main elements' (7), and below the guide plate (20) arranged in a level just below or near the splash zone, and possibly above the splash zone.

12. A system according to claim 1,
characterized in
a derrick (30') being arranged movable on a pair of first horizontal rails (32), and an additional second pair of horizontal rails (31) arranged at right angles with respect to the first rails (32).

13. A system according to claim 6,
characterized in that the rails (32) are arranged with a part extending outside of the riser moonpool (25') and arranged to allow the derrick (30'), preferably together with the second pair of rails (31) can be displaced horizontally away from the space above the riser moonpool (25') and outside the guide frame (2) so there is formed a vertical free passage over the entire riser moonpool (25') for the guide frame (2).

14. A system according to claim 1,
characterized in
hoisting means (26) arranged to transfer the guide frame (2)

vertically between

a lower position with the upper end of the guide frame (2) arranged in deck (10) level, and

a raised position with the lower end of the guide frame (2) arranged in level with the main pontoon (8) or bottom of the vessel.

15. A system according to claim 14,
characterized in
that the hoisting means (26) comprises wire drum winches (27).

16. A system according to claim 1,
characterized by
tanks (28) on the part of the guide frame (2) being arranged for submersion in water, wherein the tanks (28) are arranged to buoyancy or ballasting of the guide frame (2).

17. A system according to claim 16,
characterized in
that the tanks (28) are provided with compressed air means (29) arranged for draining of the water containment of the tanks (28) under the sea surface.

18. A system according to claim 1,
characterized in
that the number of vertical main members (7) is four, and that the guide frames (20) are mainly square or rectangular.

19. A system according to claim 6 or 7,
characterized in
that the wheels (17) are arranged in groups comprising four wheels (17) arranged in each square-shaped cell opening in the framework (21).

20. A system according to claim 8,
characteriz d in
each buoyancy member (4,5) comprising at least four bulkheads (45).

21. A system according to one of the above claims, characterized in
that in the upper parts of the guide frame (2) where the riser does not need buoyancy elements, the wheels (17) are arranged on splittable plates (121) being hinged in the beams (21') and arranged for being turned 90 degrees up and away from the riser pipe (3), in order to give free path for buoyancy elements (4,5) while these are to be lowered or taken up, and while a maintenance tool shall pass from the work deck (10) down between the beams (21') of one or more the guide plates (20) of the guide frame (2).

22. A guide frame (2) for riser pipes (3) with the guide (2) frame for arrangement on a preferably semisubmersible petroleum production vessel (1) for use at large sea depths, for buoyancy members (4,5) arranged on the riser pipes (3) arranged to carry a Christmas tree (6) on top of each riser pipe (3), comprising
characterized in

a) main members (7) for vertical arrangement from the deck (10) of the vessel (1), through the splash zone and down below the upper more wave- and current-influenced zone of the sea, to a depth between 50-150 metres.
b) guide plates (20) for the riser pipes (3) arranged in at least two levels on the guide frame (20): in levels with the lower end of the vertical main members (7), in level at or just below the splash zone, and possibly at one or more intermediate levels;
c) that the guide plates (20) are arranged with openings (22) for setting of riser pipes (3) and buoyancy members (4,5), and with members (21, 21') for lateral stabilization of the riser pipes (3) and the buoyancy members (4, 5).

23. A guide frame according to claim 22, characterized in
that the openings (22) in the guide plates (20) in all levels are arranged for setting of the main buoyancy elements on the riser (3) from above, down down through the

openings (22) in the guide plates (20).

24. A guide frame according to 22,
characterized in
that the stabilizing devices (24) for sideways stabilizing of the riser pipes (3) and the main- or auxiliary buoyancy elements (4,5) comprise wheels (17) with their axles (17') arranged in the openings formed by the cells formed by the horizontally lying framework (21) of beams (21') in the guide plates (20), arranged with the wheels's (17) tread surface to roll against the main buoyancy elements (4) or auxiliary buoyancy elements (5), or against the riser pipe (3) in the axial (operationally vertical) direction, in order for the buoyancy elements (4,5) and the riser pipe (3) to be guided vertically with respect to the guide frame (2) and the semisubmersible platform (1).

25. A guide frame according to claim 24,
characterized in
that each wheel (17) is arranged essentially diagonally near a framework node in a cell formed of beams (21') in a guide plate (20), directed towards the riser centerline, with the axle (17') extending horizontally and having an angle of about 40 to 45 degrees deviation from a beam (21').

26. A guide frame according to claim 24,
characterized in
that the at least one pair of the wheels (17) is arranged in a pair in a vertically running bogie (170) rotatable around a bogie axle (170') being parallel with the axle (17').

27. A guide frame according to claim 22,
characterized by
hoisting means (26) arranged to transfer the guide frame (2) vertically between

a lower position with the upper end of the guide frame (2) arranged aligned with a deck (10) level, and

a raised position with the lower end of the guide frame (2) arranged aligned in level with th main pontoon (8) or

bottom of the vessel.

28. A guide frame according to claim 22,
characterized by
tanks (28) arranged in or on a part of the guide frame (2) being arranged for submersion in water, wherein the tanks (28) are arranged to buoyancy or ballasting of the guide frame (2), the tanks (28) being provided with compressed air means (29) arranged for draining of the water containment of the tanks (28) under the sea surface.

29. A guide frame according to claim 22,
characterized in
that the number of vertical main members (7) is four, and that the guide frames (20) are mainly square or rectangular.

30. A guide frame according to claim 24,
characterized in
that the wheels (17) are arranged in groups comprising four wheels (17) arranged in each square-shaped cell opening in the framework (21).

31. A guide frame according claim 24,
characterized in
that in the upper parts of the guide frame (2) where the riser does not need buoyancy elements, the wheels (17) are arranged on splittable plates (121) being hinged in the beams (21') and arranged for being turned 90 degrees up and away from the riser pipe (3), in order to give free path for buoyancy elements (4,5) while these are to be lowered or taken up, and while a maintenance tool shall pass from the work deck (10) down between the beams (21') of one or more the guide plates (20) of the guide frame (2).

32. A petroleum production riser buoyancy element (4), the main buoyancy element (4) essentially comprising a right circular cylinder with an outer cylindrical [vertical] sidewall closed by circular endpieces (46) at the upper and lower ends,

characterized by
an inner pipe (47) extending centrally and axially inside the cylindrical wall (44) and forming an open channel (47') through centrally arranged holes in both endpieces (46), the open channel (47') having an inner diameter being larger than the outer diameter of a section of riser pipe (3), to provide room for curving of the section of riser pipe (3) inside the channel (47'), and

an upper clamp arrangement (43B) in the central channel (47'), arranged for clamping an upper hangoff shoulder (43A) at a section of a riser pipe (3) and arranged for taking up both horizontal and vertical forces between the buoyancy element (4,5) and the riser pipe (3) section, and

a horizontally supporting member (42B) arranged in the lower part in the central channel (47'), allowing a relatively short free relative vertical movement of the riser pipe (3) in the channel (47').

33. A petroleum production riser buoyancy element according to claim 32,
characterized in
that the buoyancy members (4,5) are provided by radial, standing bulkheads (45) arranged between the inside of the outer cylindrical wall (44) and the corresponding radially "outer" cylindrical surface of the inner pipe (47), the number of bulkheads (45) corresponding to the number of wheels (17) arranged around the buoyancy member (4,5), the bulkheads (45) being arranged as a backing of the cylindrical wall (44) against forces from wheels (17), arranged in a guide frame (2), for running on the outside of the cylindrical wall (44).

34. A petroleum production riser buoyancy element according to claim 32,
characterized by
at least one auxiliary buoyancy member (5) similar to, but having lesser diameter than the main buoyancy members (4), and arranged for being attached on a riser pipe (3) above the at least one main buoyancy member (4) and essentially

below the splash zone, and being arranged to carry the riser pipe's (3) local weight above the main buoyancy member (4).

35. A petroleum production riser buoyancy element according to claim 32,
characterized by
an upper hangoff shoulder (43A) arranged at a section of a riser pipe (3) and arranged for being clamped by an upper clamp arrangement (43B) in the central channel (47'), designed for taking up both horizontal and vertical forces between the buoyancy element (4,5) and the riser pipe (3) section, and a pair of horizontally supporting member (42A) on the riser pipe (3) section cooperating with a member (42B) in the central channel (47'), allowing a relatively short free relative vertical movement of the riser pipe (3) in the channel (47').

36. Semisubmersible production platform (1) with dry wellheads and Christmas trees (6), with a guide frame (2) for one or more riser pipes (3),

with one or more main buoyancy member (4) arranged separately on at least one riser (3) to carry the main part of the riser's (3) weight,

each riser (3) arranged to separately carry a Christmas tree (6) on top, near the main deck (10) of the vessel (1),

the guide frame (2) comprising vertical main elements (7) arranged to extend vertically downwards from the deck (10), through the splash zone and through the upper, more wave- and current-influenced zone of the sea,
characterized by

the guide frame (2) having horizontal guide plates (20) comprising vertically open cells formed of a horizontally arranged framework (21) of beams (21'), with lateral stabilization devices (24) for guiding the risers' (3) and the main buoyancy members' (4) vertical relative movement and restricting the horizontal relative movement with respect to the guide frame (2),

the guide plates (20) being arranged in at least two levels on the guide frame (2); a lower guide plate (20)

arranged in level with the lower ends of the vertical main elements' (7), and a guide plate (20) arranged in a level just below or near the splash zone,

that one main buoyancy member (4) is arranged for being held on the riser (3) in level with, and guided by the lateral stabilization devices (24) arranged in at least one guide plate (20) arranged below the upper, more wave- and current-influenced zone near the sea surface, and with the risers (3) being essentially without buoyancy elements through the splash zone, for being less exposed to the water forces in the upper zone of the sea.

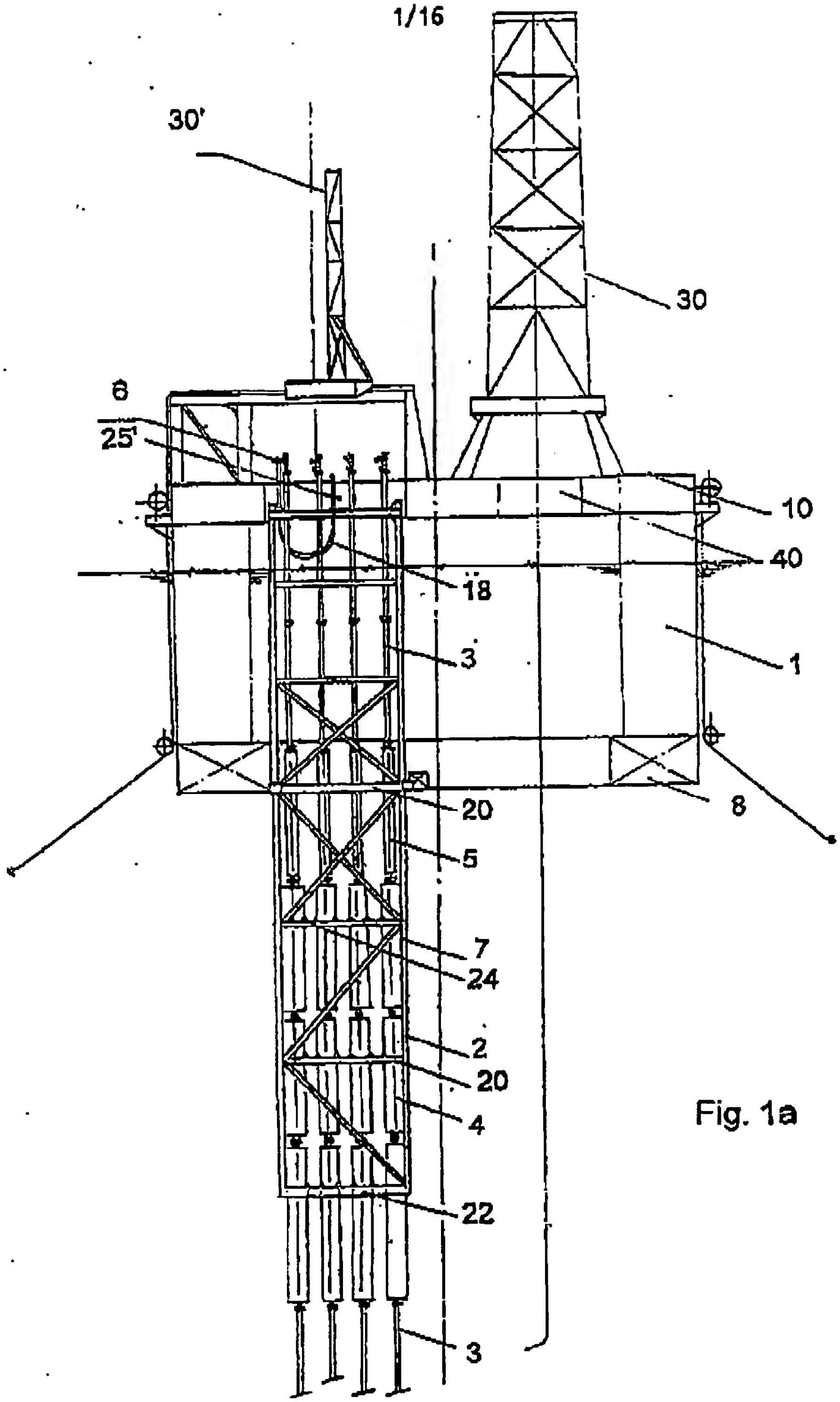


Fig. 1a

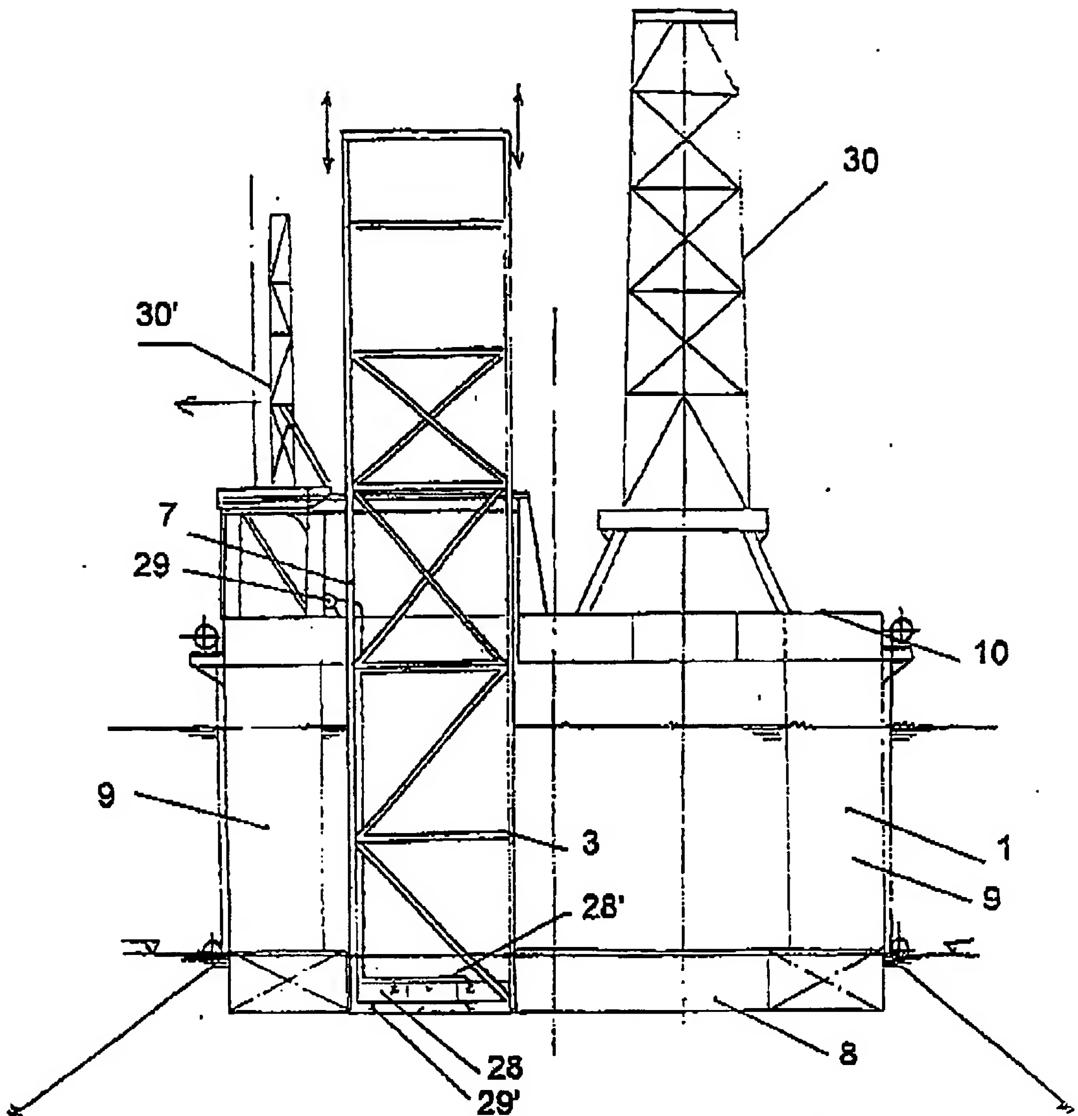


Fig. 1b

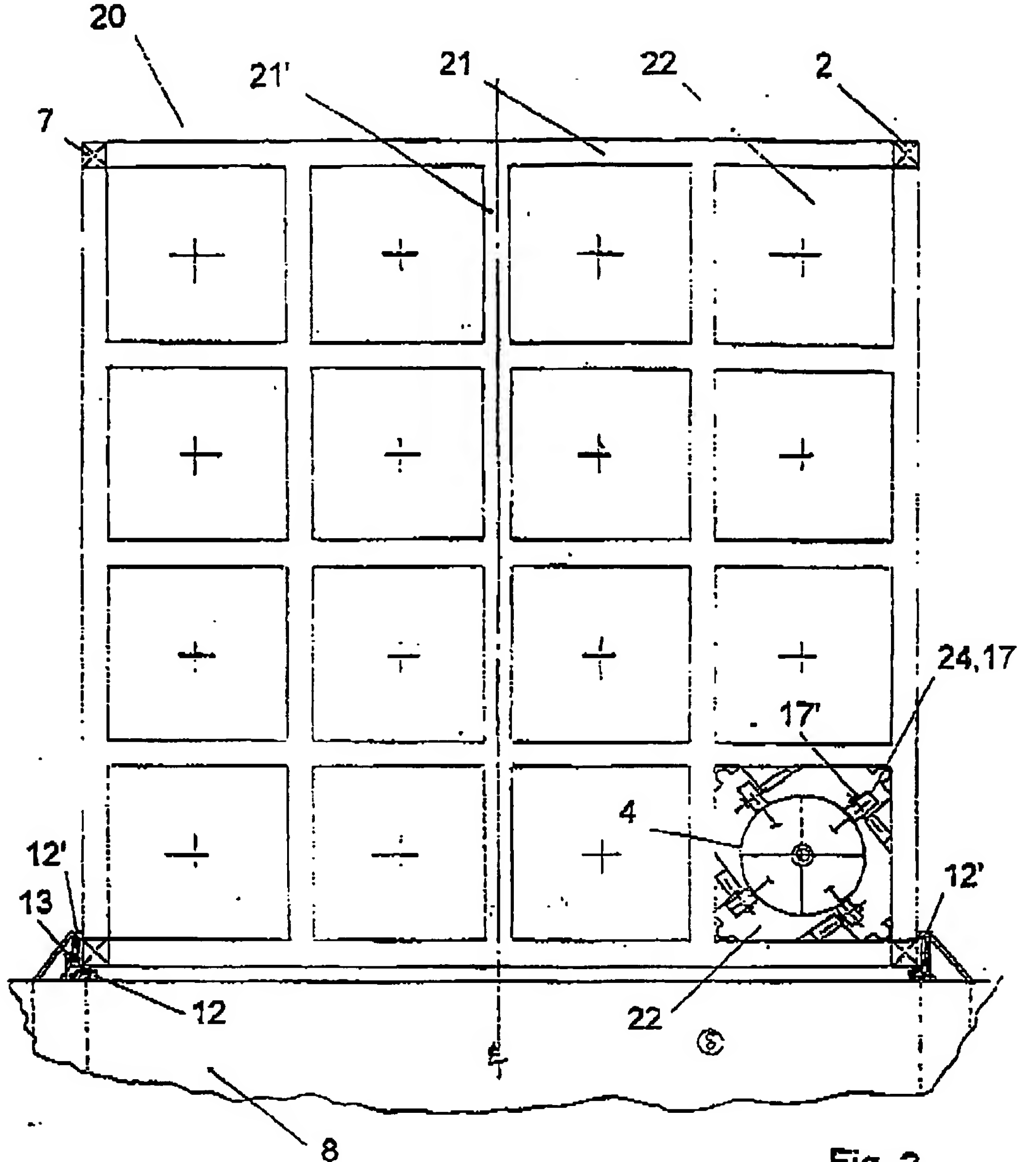


Fig. 2

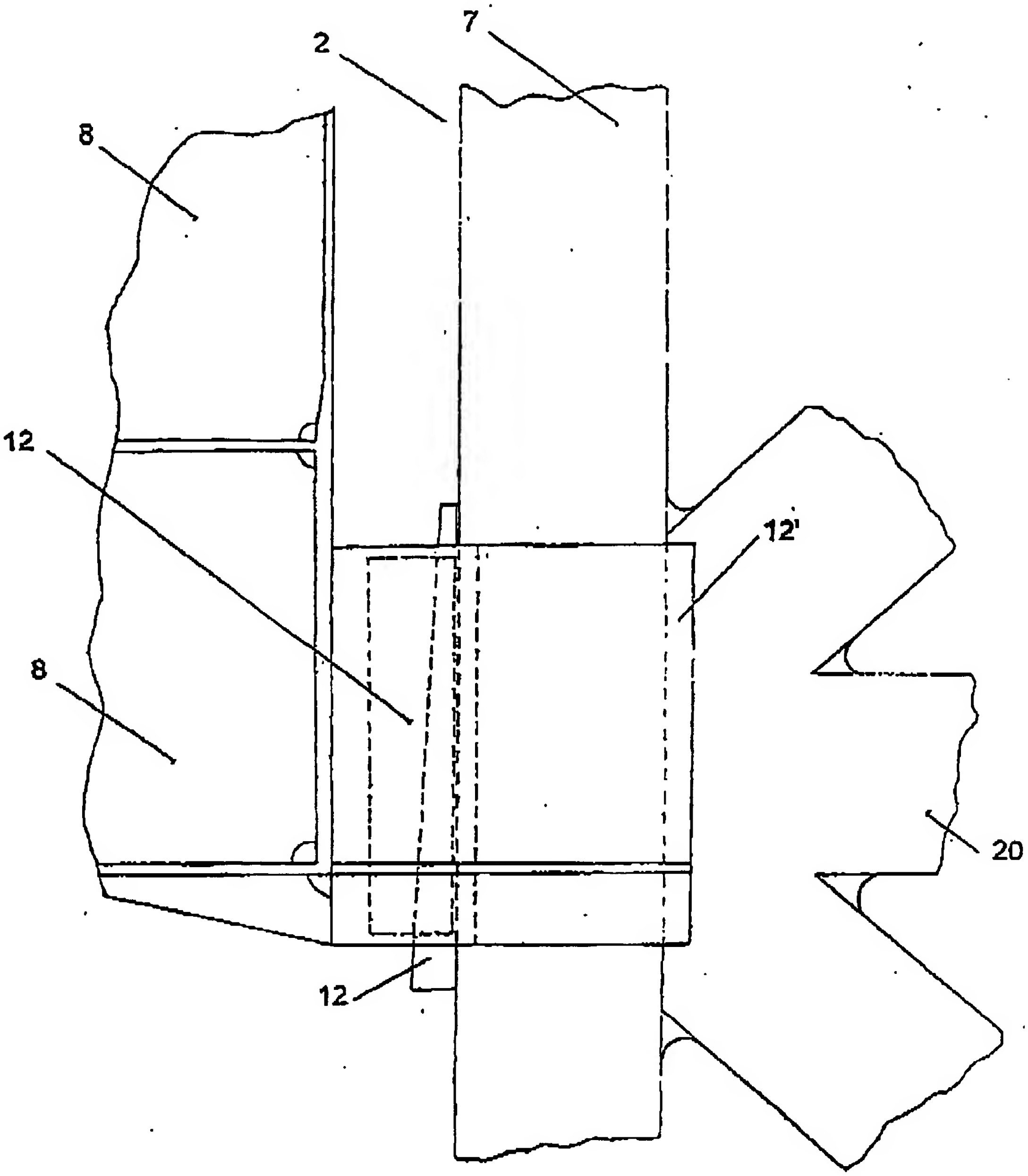


Fig. 3

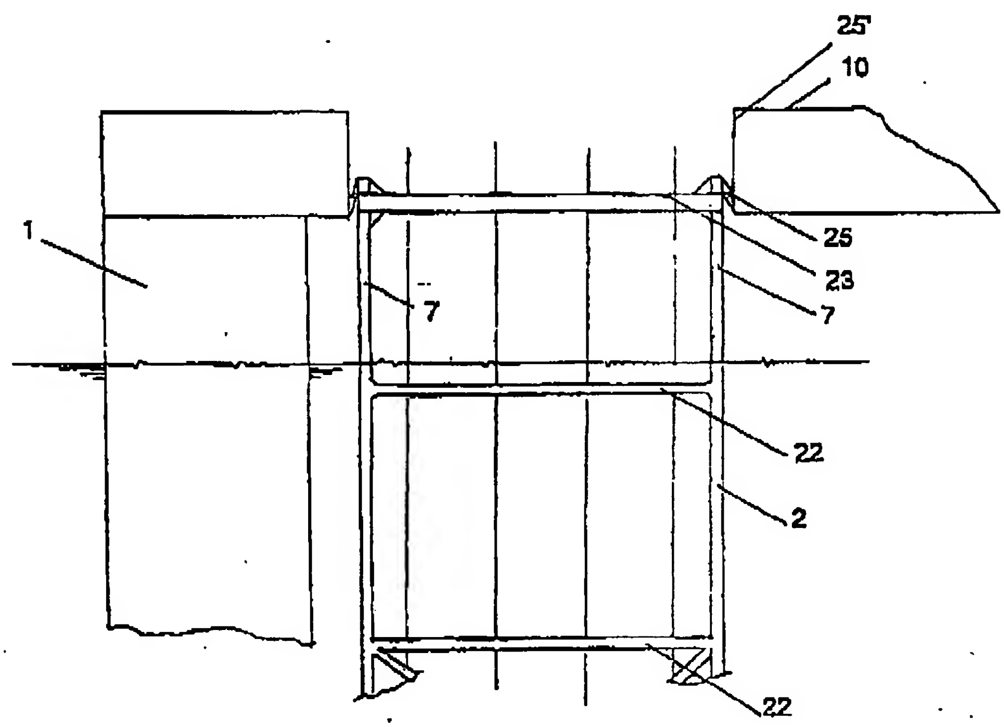


Fig. 4

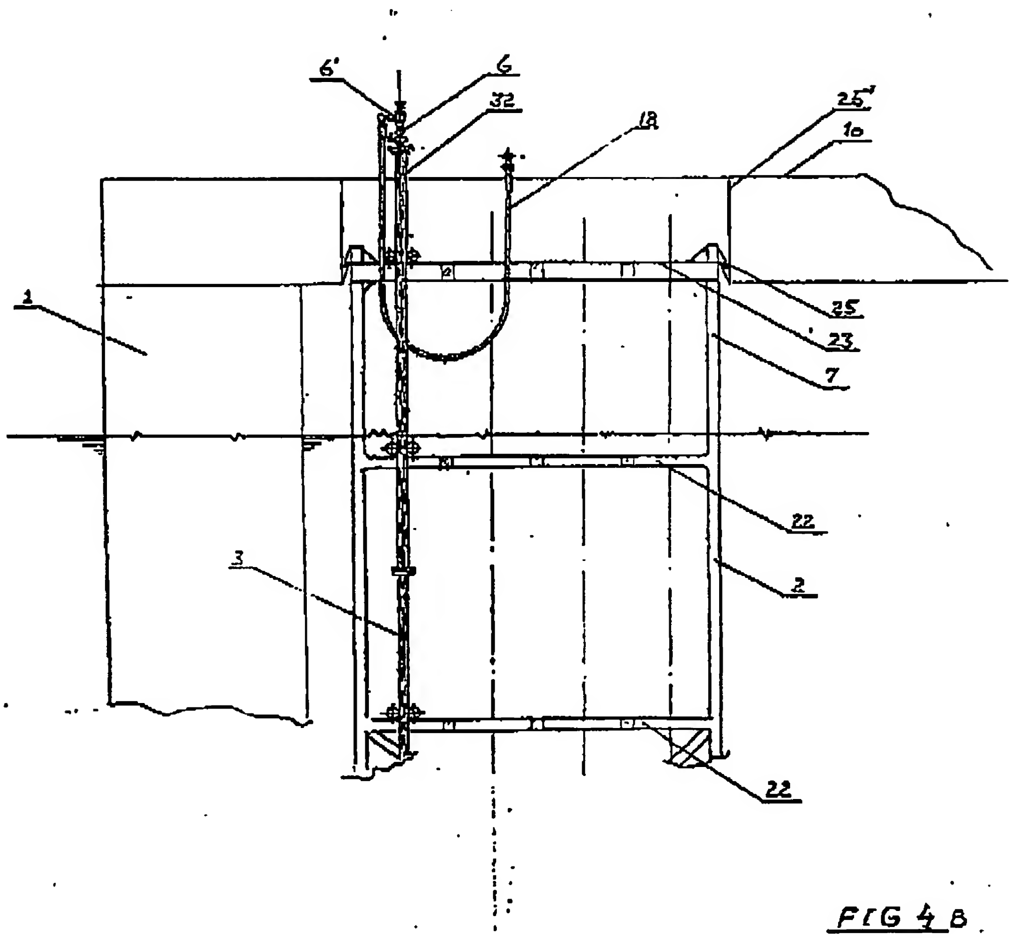


FIG 4B

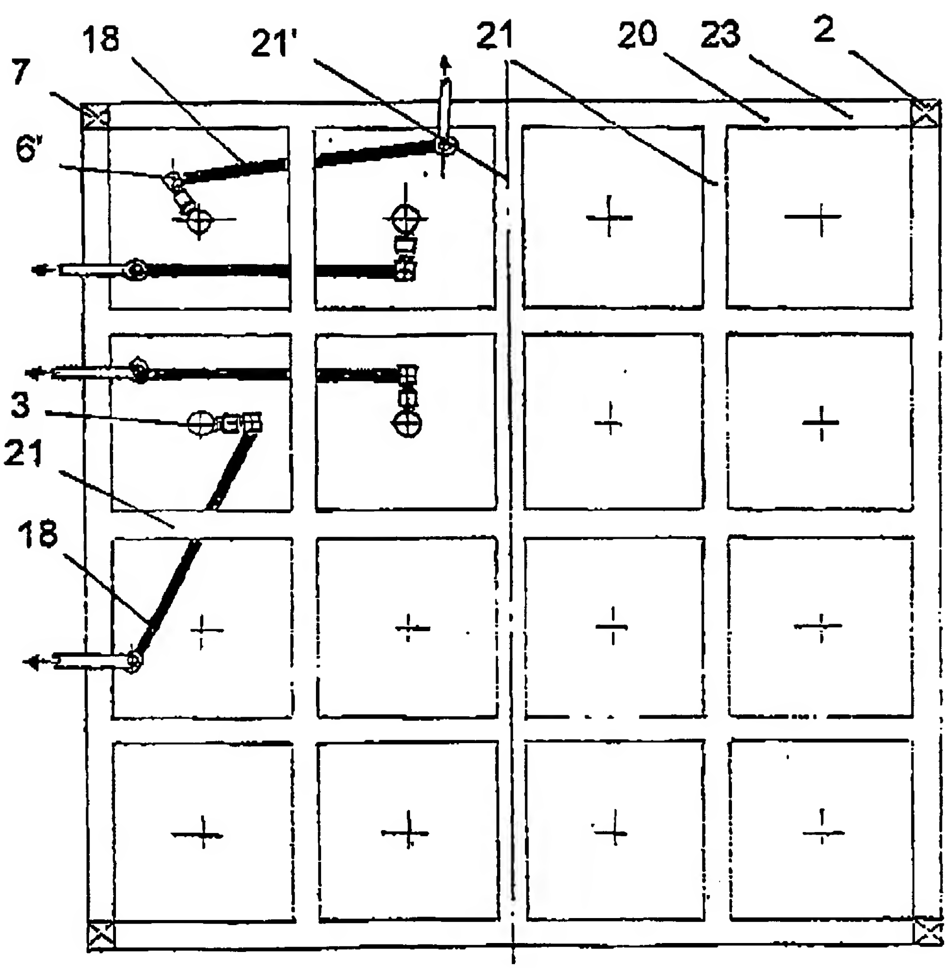


Fig. 4C

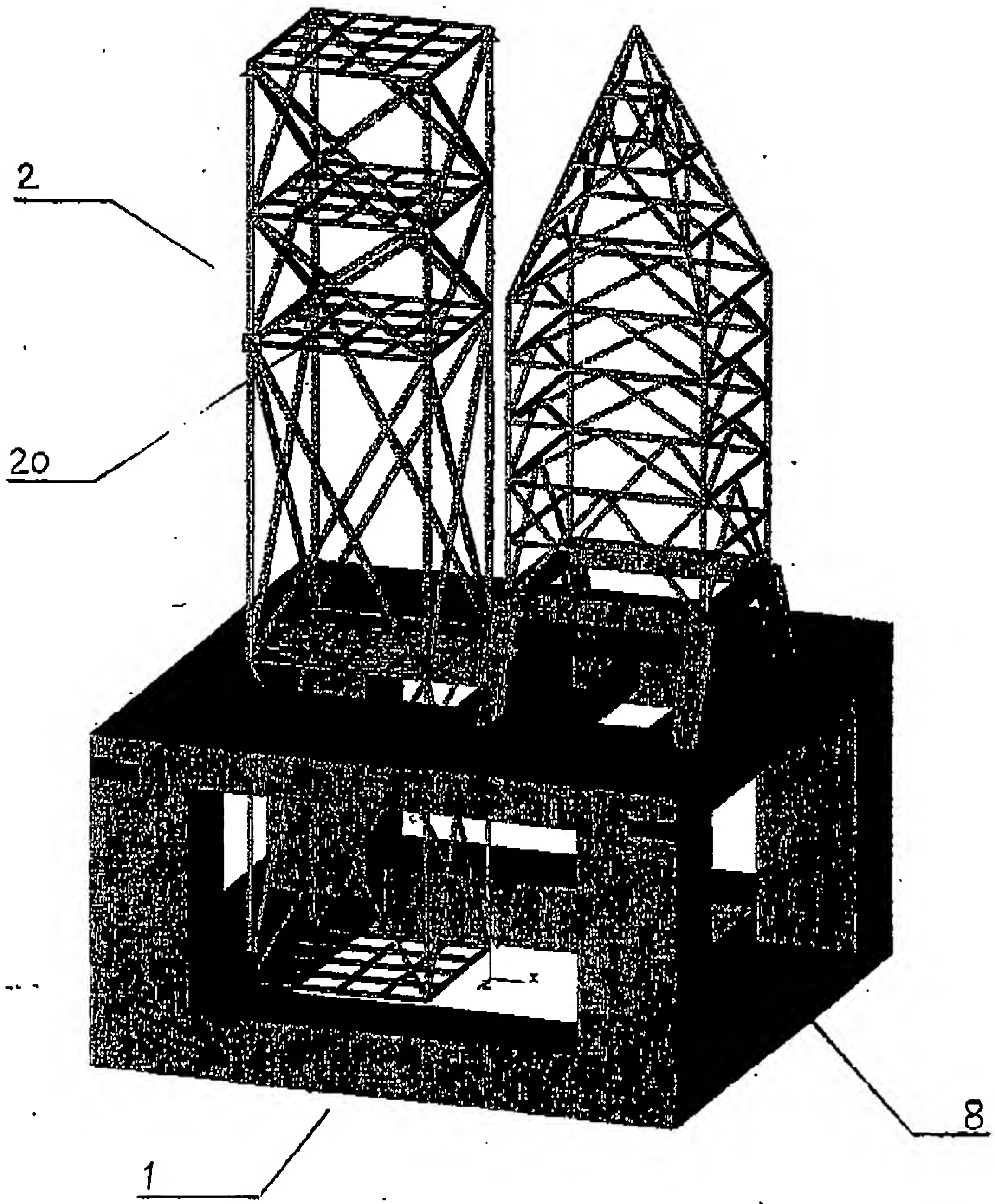


Fig. 5a

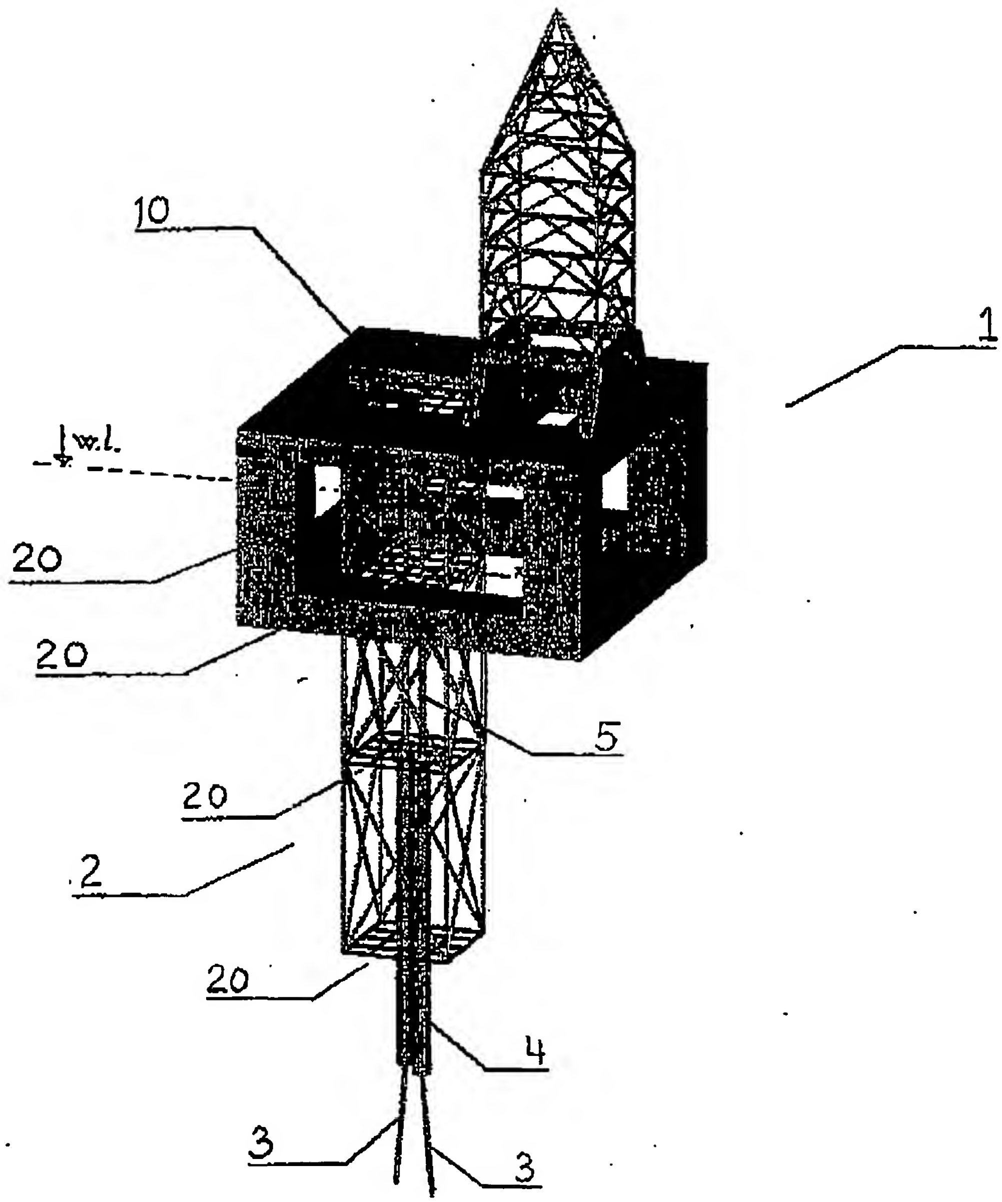


Fig. 5b

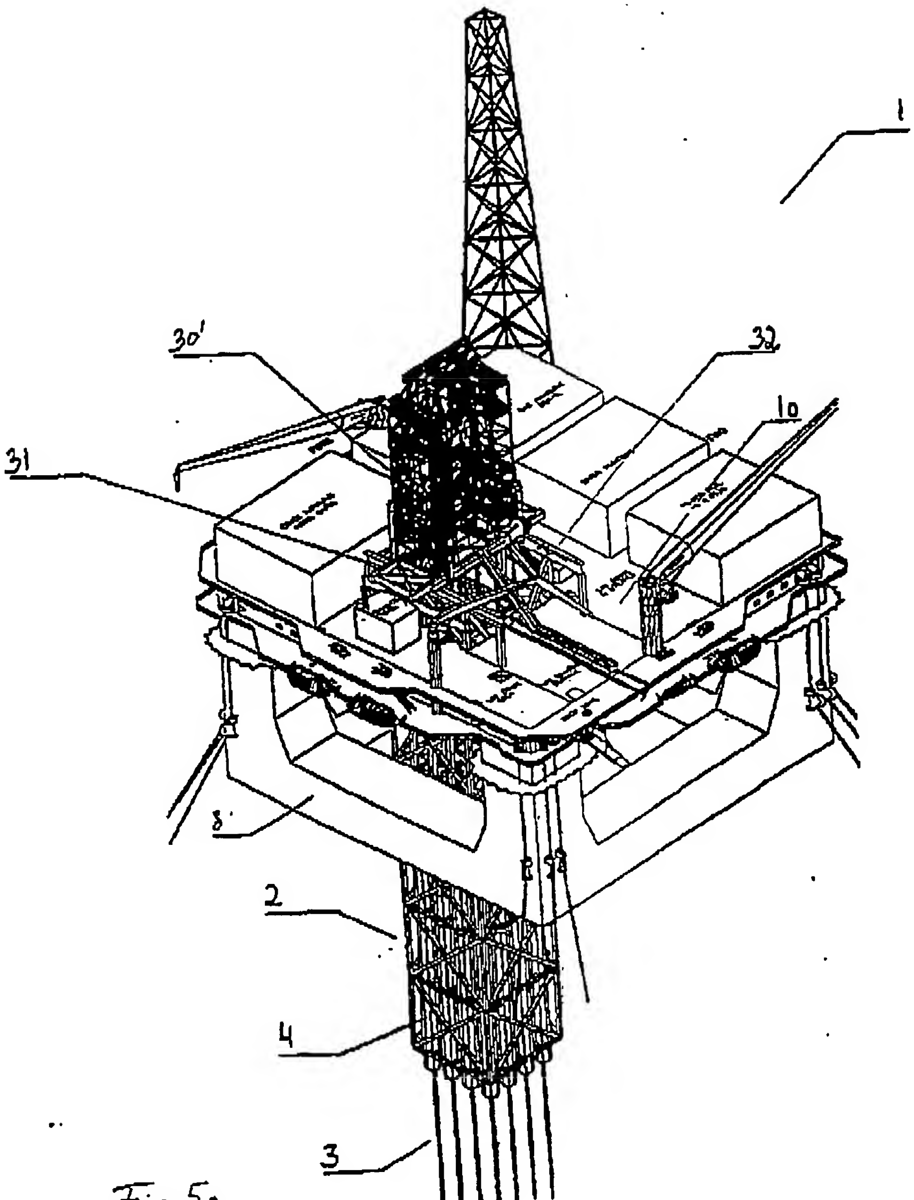


Fig 5c

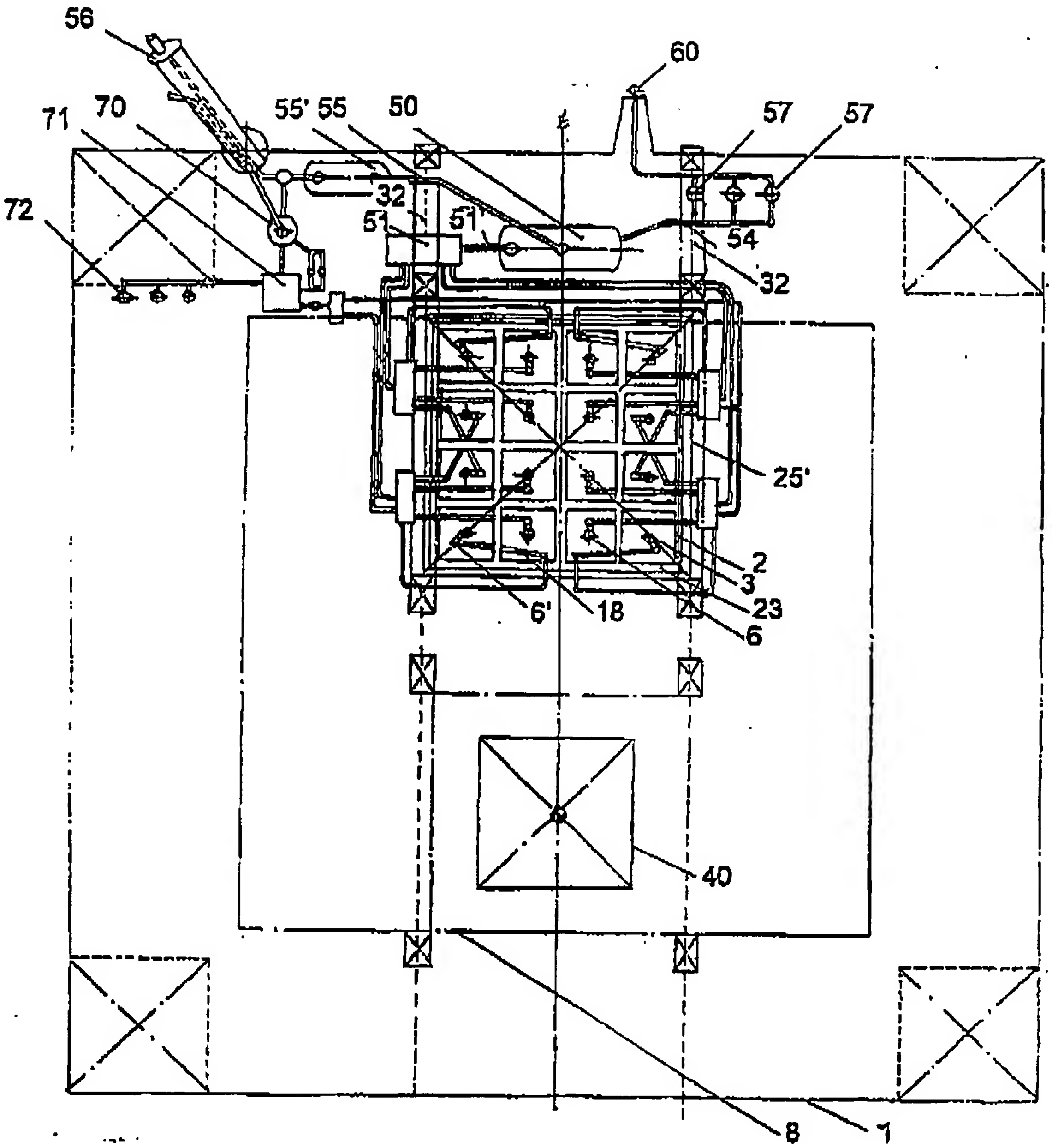


Fig. 6

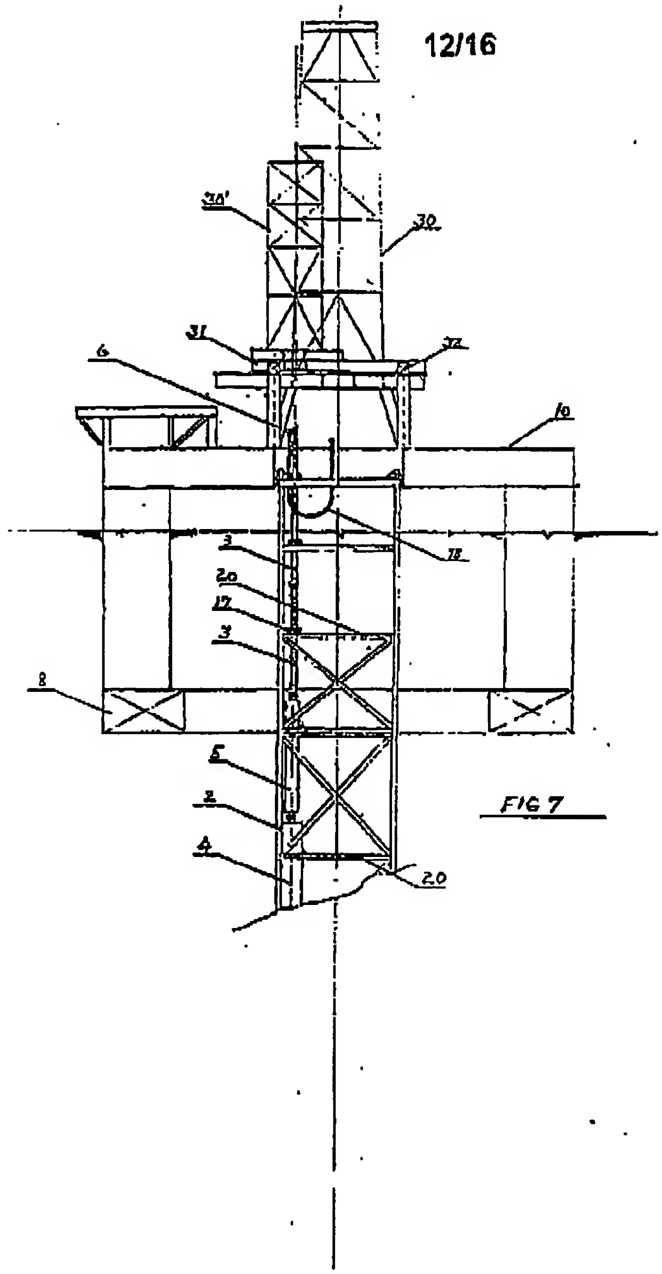


FIG 7

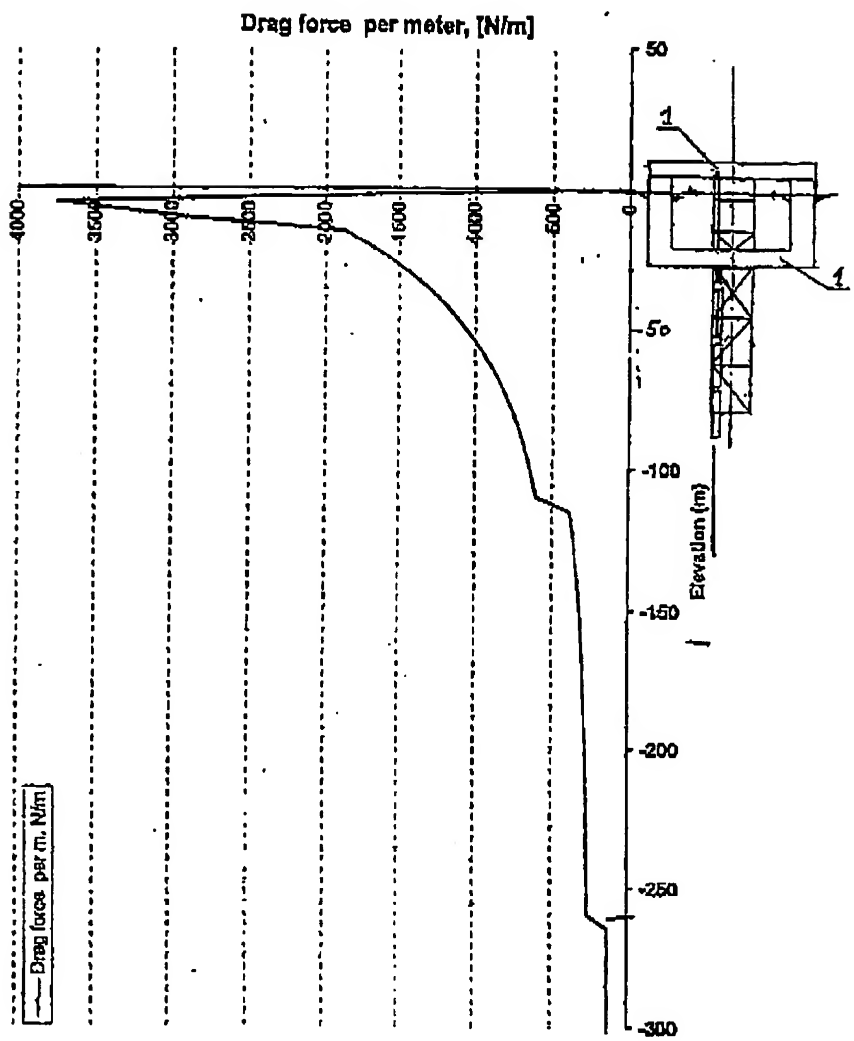

Drag force per meter, [N/m]
4000
3500
3000
2500
2000
1500
1000
500
0
50
-50
-100
-150
-200
-250
-300
Elevation (m)
Drag force per m, N/m
1
1

FIG 8

Tension along riser, [Newton]

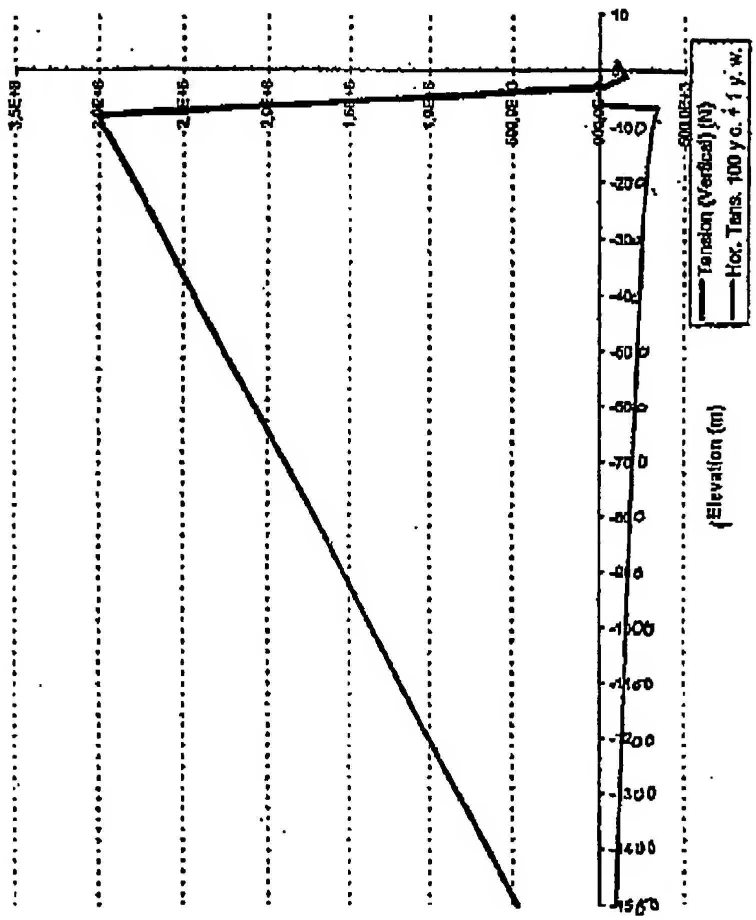


Fig. 9

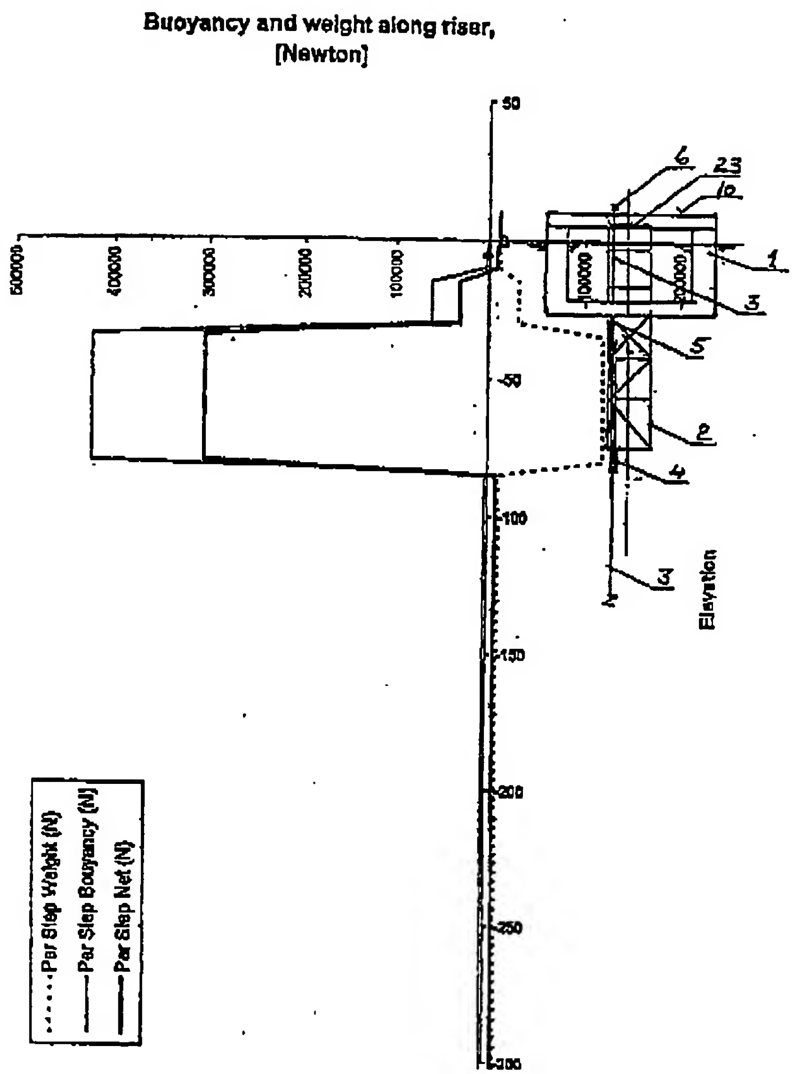
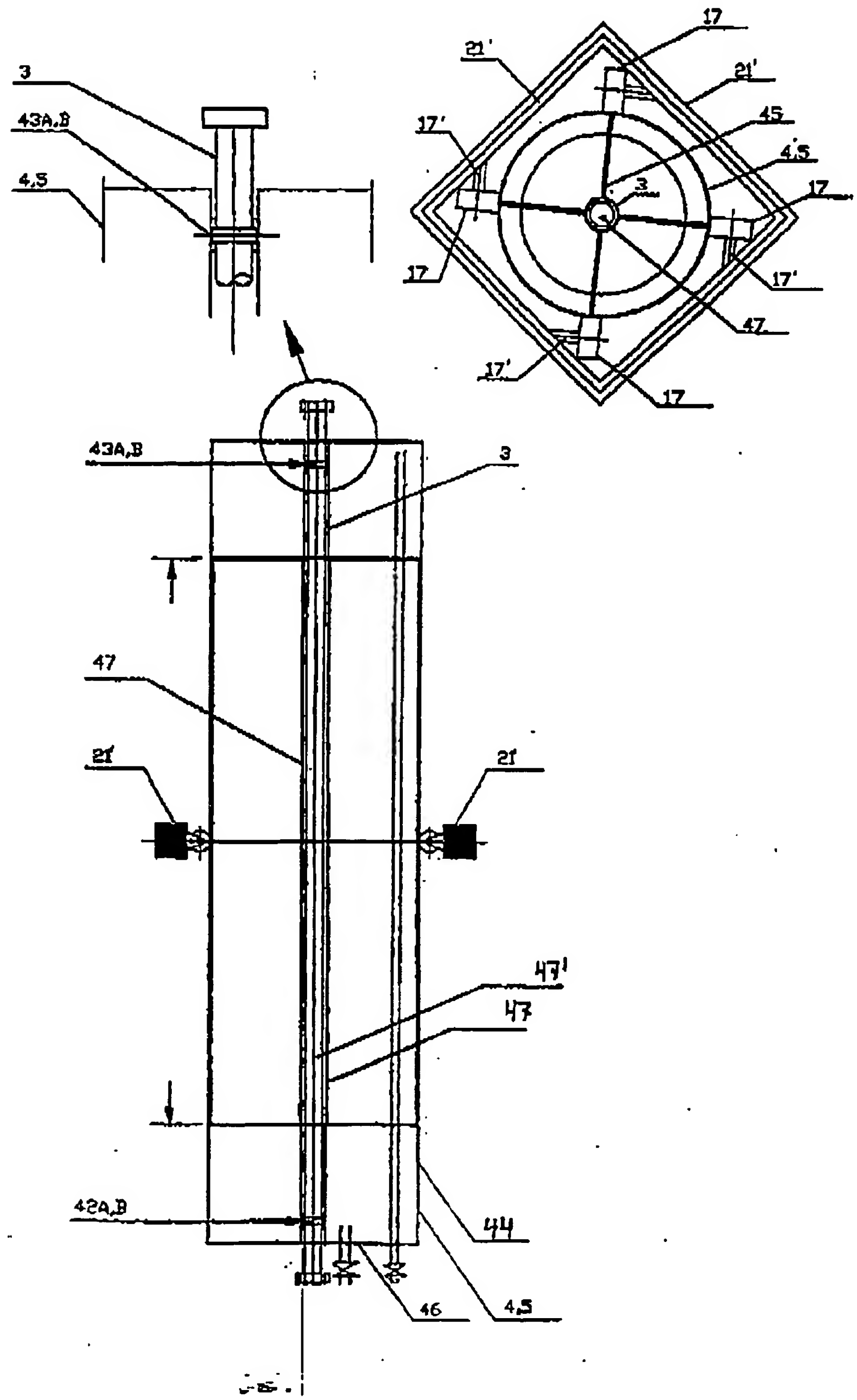

Buoyancy and weight along riser,
[Newton]
500000
400000
300000
200000
100000
100000
200000
50
-50
-100
-150
-200
-250
-300
Elevation
6
23
10
1
3
5
2
4
3
Per Step Weight (N)
Per Step Bouyancy (N)
Per Step Net (N)

Fig 10.

FIG. 11


3
43A,B
4,5
17
21'
21'
45
4,5
17'
3
17
17
17'
47
17'
17
43A,B
3
47
21'
21'
47'
47
42A,B
44
46
4,5

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 00/00106

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: E21B 19/24
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: E21B, B63B, E02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2139570 A (GEORGE COLLINGWOOD COPSON), 14 November 1984 (14.11.84) --	1-36
A	GB 2147549 A (EARL AND WRIGHT), 15 May 1985 (15.05.85) --	1-36
A	US 4126183 A (WALKER), 21 November 1978 (21.11.78) --	1-36
A	US 5558467 A (HORTON), 24 Sept 1996 (24.09.96) -- -----	1-36

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
11 July 2000	20 -07- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Christer Bäcknert / JA A Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT
Information on patent family members

02/12/99

International application No.
PCT/NO 00/00106

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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GB 2147549 A	15/05/85	AU 3426984 A	26/04/85
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		AU 4155496 A	31/05/96
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		CA 2202151 A	17/05/96
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		WO 9614473 A	17/05/96